ACHIEVABLE SPACE ELEVATORS FOR SPACE TRANSPORTATION AND STARSHIP ACCELERATION

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ABSTRACT

Space elevator concepts for low-cost space launches are reviewed. Previous concepts suffered from requirements for ultra-high-strength materials, dynamically unstable systems, or from danger of collision with space debris. The use of magnetic grain streams, first proposed by Benoit Lebon, solves these problems. Magnetic grain streams can support short space elevators for lifting payloads cheaply into Earth orbit, overcoming the material strength problem in building space elevators. Alternatively, the stream could support an international spaceport circling the Earth daily tens of miles above the equator, accessible to advanced aircraft. Mars could be equipped with a similar grain stream, using material from its moons Phobos and Deimos. Grain-stream arcs about the sun could be used for fast launches to the outer planets and for accelerating starships to near lightspeed for interstellar reconnaisance. Grain streams are essentially impervious to collisions, and could reduce the cost of space transportation by an order of magnitude.

INTRODUCTION

The major obstacle to rapid space development is the high cost of launching payloads into Earth orbit. Current launch costs are more than $3000 per kilogram, and rocket vehicles such as NASP, Sänger, or the Advanced Launch System will still cost $500 per kilogram. The prospects for space enterprise and settlement are not good unless these high launch costs are reduced significantly.

Over the past thirty years, several concepts have been developed for launching large payloads into Earth orbit cheaply using "space elevators." These structures can be supported by either static force balance or by the dynamics of moving masses. Their construction faces several technical difficulties, however. Enormous masses must be launched into orbit by conventional rockets to start the systems, extremely high-strength materials must be used to build the structures, and collision with natural meteoroids or man-made debris would shorten their lifetimes.

This paper discusses a complete space transportation system encompassing Earth-to-orbit launching of large quantities of material, easy transportation without rocket propellant between Earth orbit and the moon or Mars, solar launching facilities for high-speed transportation to the outer solar system, and the acceleration of near-lightspeed interstellar spacecraft. The concepts are based on the use of a stream of magnetic grains acting as the current-carrying element of an electric motor. Spaceships equipped with superconducting solenoids to generate superhigh magnetic fields could interact with the magnetic grain stream to propel themselves at high accelerations throughout the solar system. Similar grain streams at the destinations could decelerate the spaceships without requiring on-board rocket propellants. The result would be smaller, more capable spaceships. An even more important advantage would be the drastic reduction in the cost per kilogram of Earth-orbit launches.

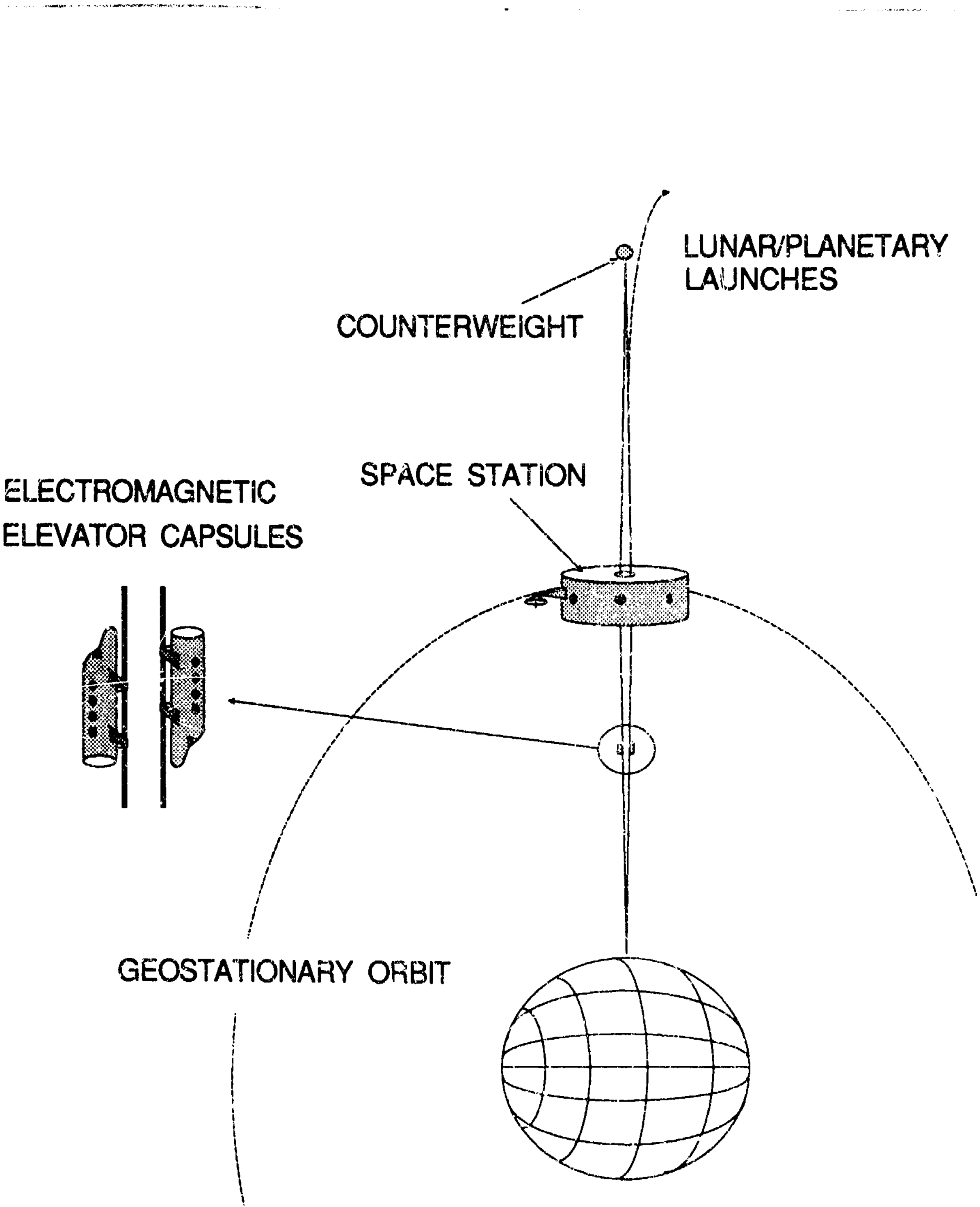

FIGURE 1. THE STATIC SPACE ELEVATOR

The classical concept for a space elevator is the statically balanced structure centered on the geostationary orbit and extended both upward and downward in balance until the lower end touches the equator; the upper end is then counterweighted to put the entire structure into tension, allowing it to lift payloads from the Earth into geostationary orbit. The concept was invented independently by Yuri Artsutanov (ref. 1.), John Isaacs, et al. (ref 2), and Jerome Pearson (ref. 3). Artsutanov proposed the launching of Earth-escape launches from the upper tower, and Pearson proposed the two-way traffic of electromagnetic vehicles from the ground to the geostationary space complex without external power. The concept requires an enormous amount of high-strength material and is vulnerable to severing by collision with debris.

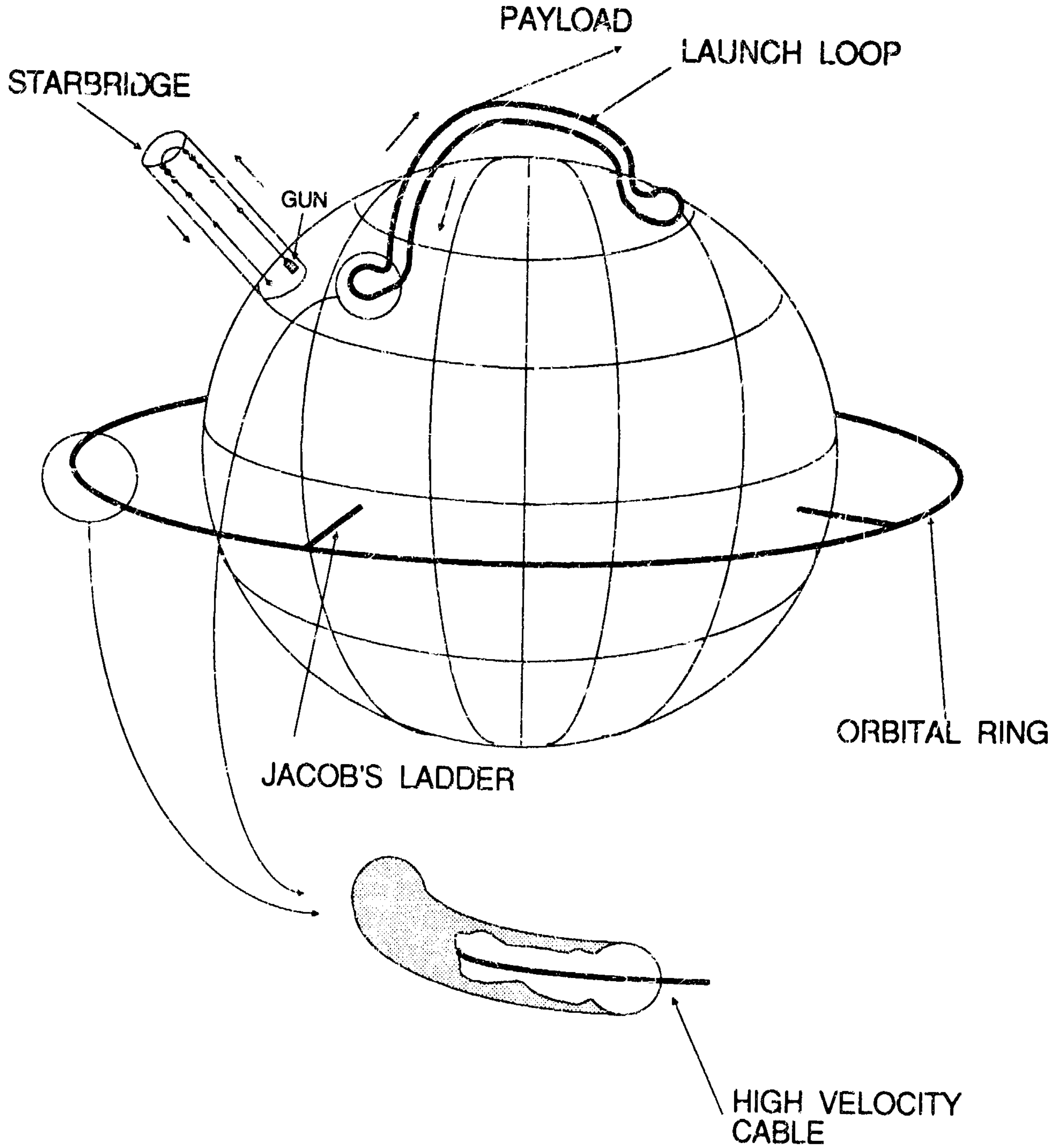

FIGURE 2. DYNAMIC SPACE ELEVATOR

To overcome the material strength and mass requirements of the static space elevator, several concepts were proposed to support space elevators by the dynamic forces of mass in motion. Paul Birch (ref. 4) proposed an orbital ring of conducting material moving faster than orbital velocity inside a thin torus circling the Earth. The moving cable produces an upward force on the torus, allowing the torus to support "Jacob's ladders" the few hundred kilometers down to the surface. Keith Lofstrom (ref. 5) and Birch proposed a similar moving conductor in a shorter "launch loop" that could accelerate electromagnetic vehicles to orbital velocity along the loop. Rod Hyde (ref. 6) proposed a purely vertical "starbridge" supported by the reaction force from accelerating downward a series of conducting rings fired upward from the base. These dynamic concepts solve the material strength problems of the space elevator, but they depen[illegible] on the fail-safe operation of fundamentally unstable dynamic systems.

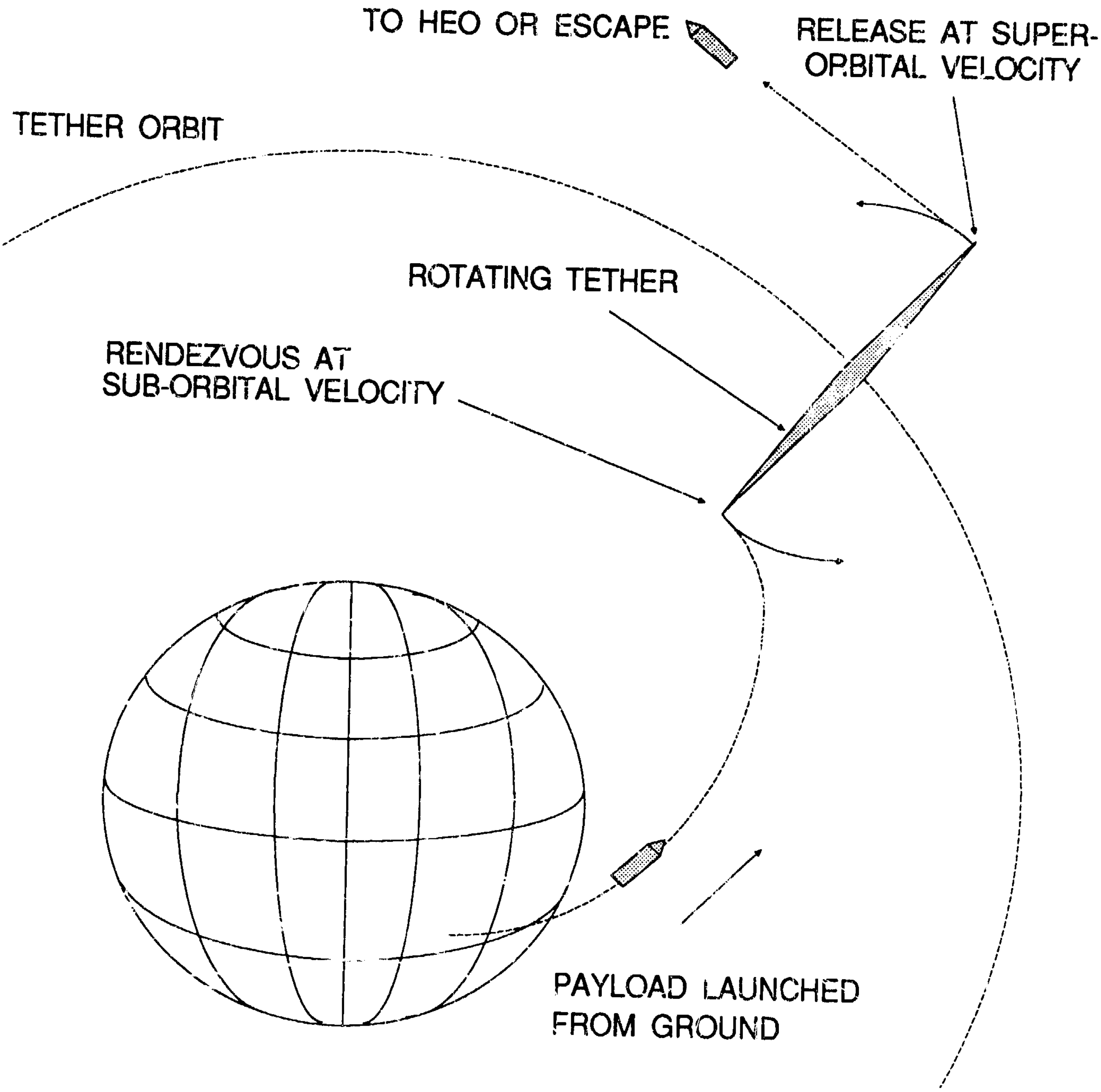

FIGURE 3. THE ROLLING SATELLITE

Yet a third way to produce the space elevator is to set the static space elevator into rotation, and catch and launch payloads from the rapidly moving ends of this "rolling satellite." A rotating tether in orbit could provide most of the orbital energy needed for a payload launched from the ground by catching it on the lower end; the tether could then launch the payload into a higher orbit or to Earth-escape by releasing it from the upper end, half a tether rotation later. If payloads returning from higher orbits are also caught and released for Earth entry, no net energy is required by the rotating tether. Artsutanov originated the concept in 1969 (ref. 7); it was invented independently by Hans Moravec (ref. 8) and put into a practical form by Pearson (ref. 9). The concept faces the problems of high-speed rendezvous and tether dynamics.

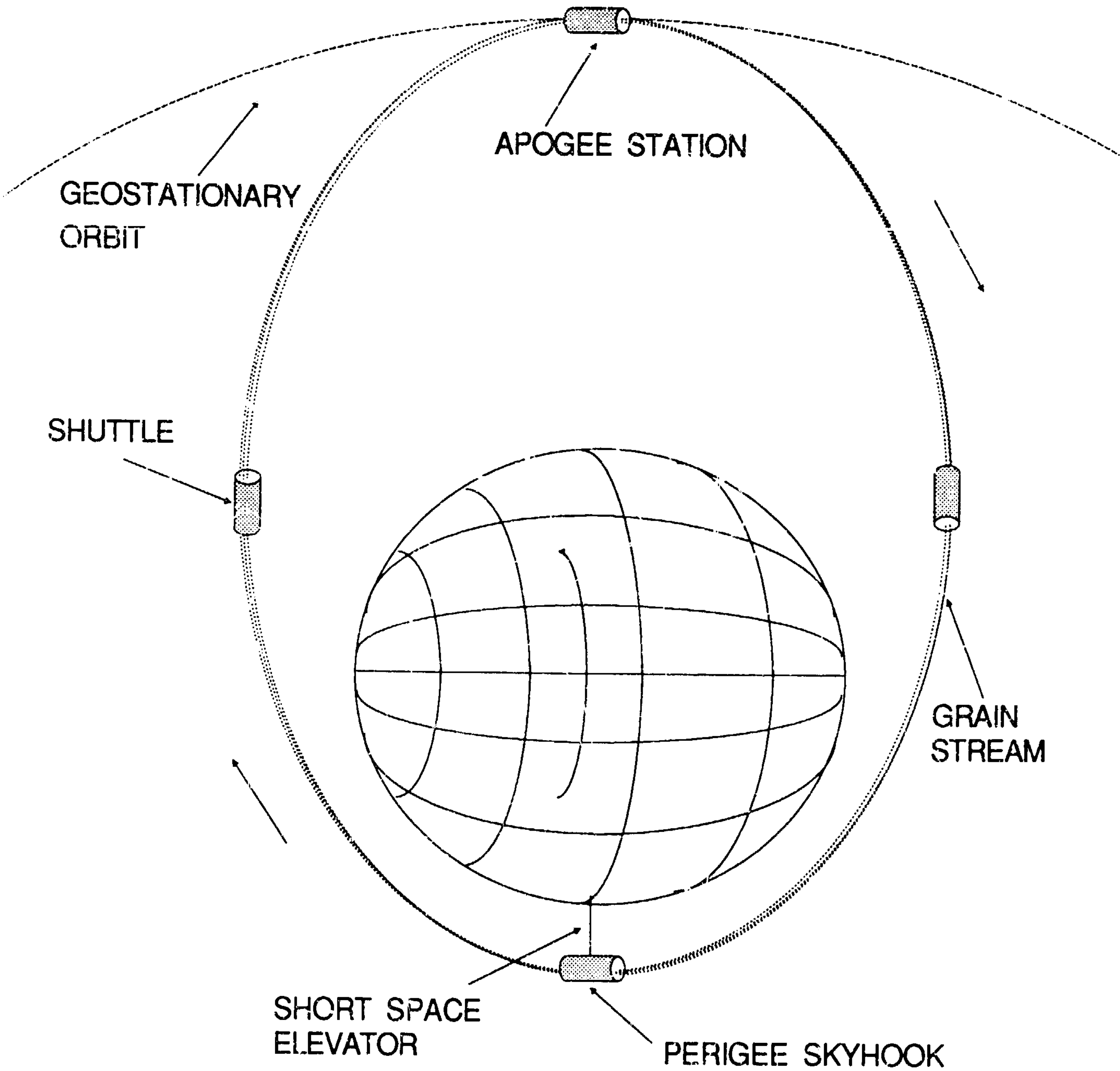

FIGURE 4. THE GRAIN-STREAM SPACE ELEVATOR

A space elevator concept that overcomes all the problems of previous attempts was proposed by Benoit Lebon in 1986 (ref. 10, 11) and elaborated upon in 1987 (ref. 12). The concept is similar to Birch's orbital ring, but it uses a much less massive stream of magnetic grains and dispenses with the massive enclosing torus. The grain stream is kept in place by shepherding solenoids that move slowly along the stream. This shepherding action is done naturally by the gravitational fields of small satellites on thin rings about Saturn and the other giant planets. The solenoidal vehicles would have a much easier job because of the far stronger magnetic forces available. A grain stream in elliptical orbit could support a large space station in geostationary orbit and a short space elevator from a perigee skyhook. The system has the advantages that it could be built in stages, increasing the stream density to carry higher payloads, and that it is impervious to collision. The short space elevator could be almost entirely in the atmosphere, where debris could not penetrate. The magnetic grains could be obtained from the moon or from a nearby asteroid.

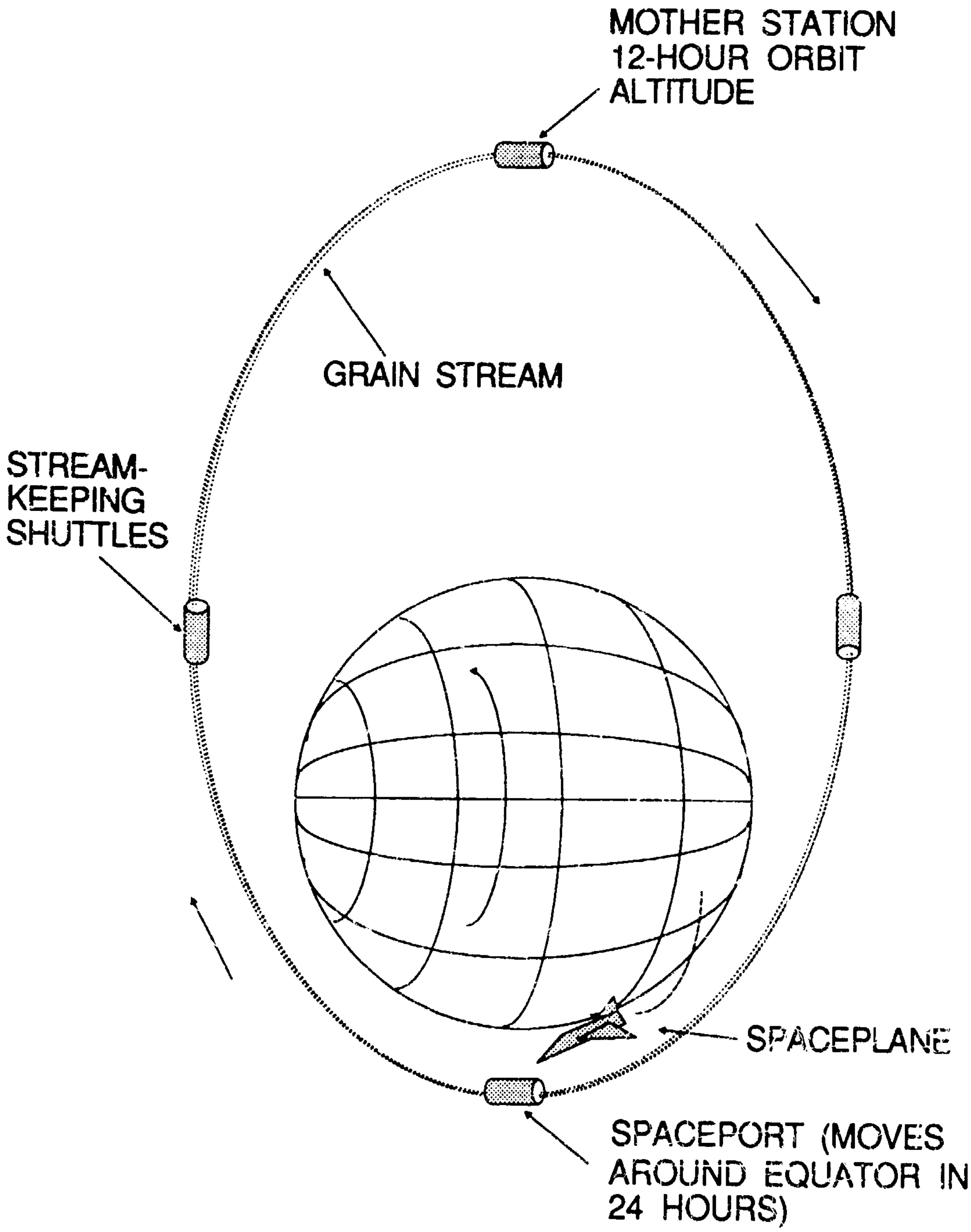

FIGURE 5 THE INTERNATIONAL "SPACE TELPHER" SYSTEM

In 1988, Lebon (ref. 13) proposed an alternate grain-stream launch system that is even more advantageous than the original. He replaced the short space elevator with a "space telpher," or travelling spaceport supported by the grain stream and moving completely around the equator once per day. This spaceport could be at less than 100 kilometers altitude, allowing advanced aircraft from all nations to reach the spaceport daily. Once there, grain-stream shuttles could move to the mother station at 12-hour orbital altitude and be launched to Earth escape. In a sense, this is a space elevator without the elevator, and it would not be tied down to one location on the equator. By not having to support an enormous elevator, the grain stream could be smaller, making the entire system simpler and cheaper.

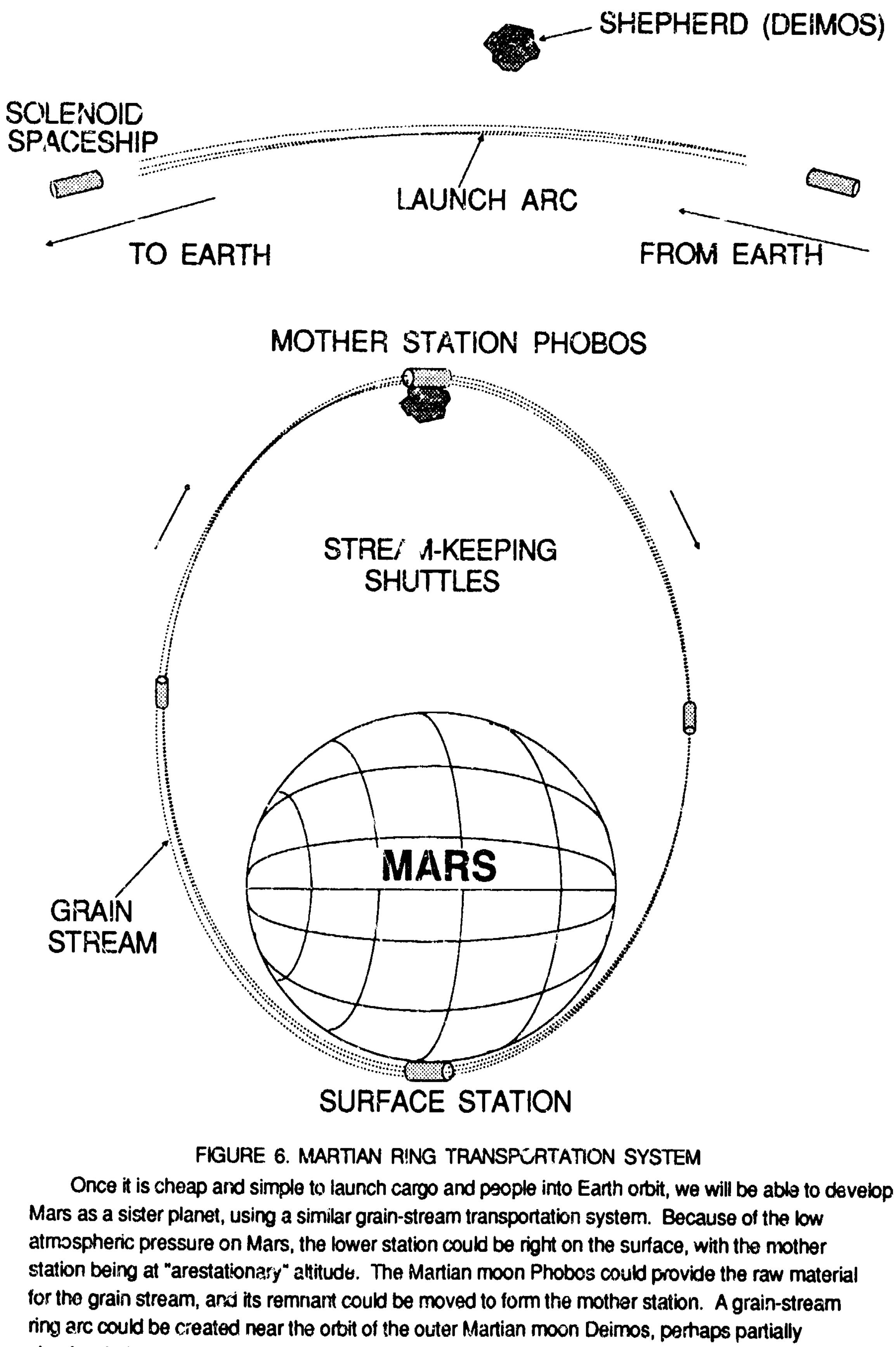

FIGURE 6. MARTIAN RING TRANSPORTATION SYSTEM

Once it is cheap and simple to launch cargo and people into Earth orbit, we will be able to develop Mars as a sister planet, using a similar grain-stream transportation system. Because of the low atmospheric pressure on Mars, the lower station could be right on the surface, with the mother station being at "arestationary" altitude. The Martian moon Phobos could provide the raw material for the grain stream, and its remnant could be moved to form the mother station. A grain-stream ring arc could be created near the orbit of the outer Martian moon Deimos, perhaps partially shepherded by Deimos itself, in addition to streamkeeping shuttles. This arc could accelerate solenoidal spaceships bound for Earth and decelerate spaceships arriving from Earth. A similar launch arc about the Earth would complete a two-planet transportation system.

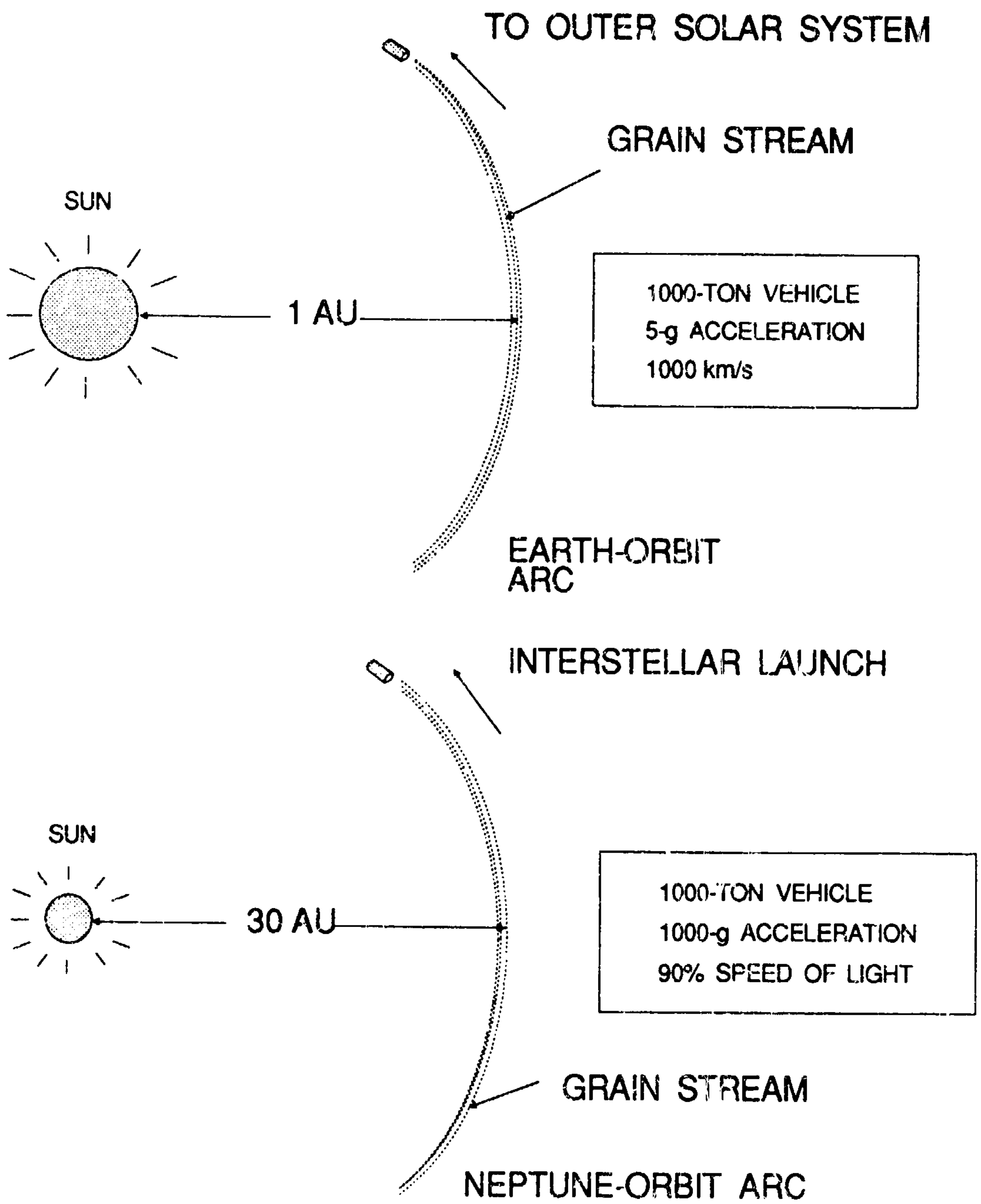

FIGURE 7. SOLAR RUNWAYS

The partial grain stream concept was originated by Lebon (ref. 11) as a method for achieving extremely high launch velocities. He proposed creating a partial ring in solar orbit at the Earth's distance from the sun, and using it to accelerate solenoidal spaceships to about 1000 km/s in order to reach the outer solar system in just a few months. The acceleration is limited by the magnetic field achievable on the spacecraft. With a field of 0.06 tesla, a 1000-ton spacecraft could be accelerated to 1000 km/s at 5 g in less than 7% of the circumference of the Earth's orbit. A larger "solar runway" could be placed about Neptune's distance from the sun for interstellar launches. A 15-tesla solenoid could accelerate a 1000-ton vehicle at 1000 g to 90% the speed of light from such an arc. Much more modest fields would suffice to launch fast interstellar probes for the initial reconnaissance of nearby planetary systems in a few decades. Ring orbit perturbations could be minimized by launching vehicles in opposite directions along the grain-stream arc.

CONCLUSIONS

The ancient dream of the space elevator is now possible. Magnetic grain streams and high-magnetic-field solenoidal spacecraft could solve the problem of the high cost of space launching and result in rapid space colonization and industrialization. This form of space transportation could also greatly reduce the travel time to the outer solar system, bringing the resources of the outer planets into our realm. Finally, grain-stream arcs in solar orbit could be the launching ramps for fast reconnaissance missions to the nearby stars that could provide data on extra-solar planetary systems within a decade or two of launch.

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